Estimates of the Upper Ocean Heat Budget in the North Atlantic in Three Models

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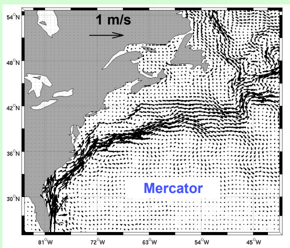
Introduction

Three models, a diagnostic model driven by observations, an assimilative ocean model, and a prognostic ocean model are used to evaluate the upper ocean heat budget (upper 800m) in the Gulf Stream (Box 1) and the North Atlantic Current (Box 2). We focus here on 1993-1999 to make direct comparisons between the different date sets. We also examine the relationship between SSH anomalies and heat transport anomalies to determine if the mechanism for heat transport anomalies is consistent between the models.

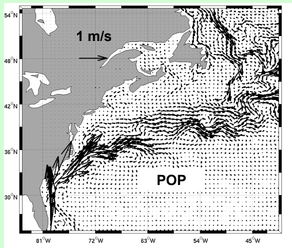
The Models

Surface currents

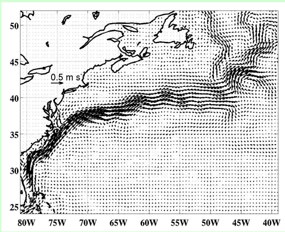
•Mercator
- –Daily ECMWF ERA 40 winds
- –MERA11 1/3° resolution
- –Assimilates in situ and satellite observations
- –Monthly averages



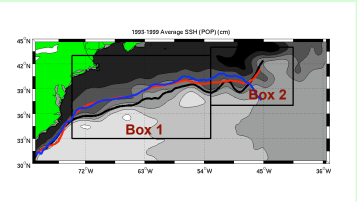
•POP (Parallel Ocean Program)
- –1/10° resolution
- –Prognostic model
- –Daily NCEP forecast winds
- –Relaxation to climatology at northern (72N) and southern boundaries (20S)
- –21 day averages



•Diagnostic Model
- –Daily NCEP winds
- –Advection via altimetry derived currents with climatological vertical structure
- –Upstream boundary condition from observations
- –Heat flux derived from NCEP fields
- –After Dong and Kelly (2004)
- –Mean from Maximenko and Niiler (2004)
- –5 day averages

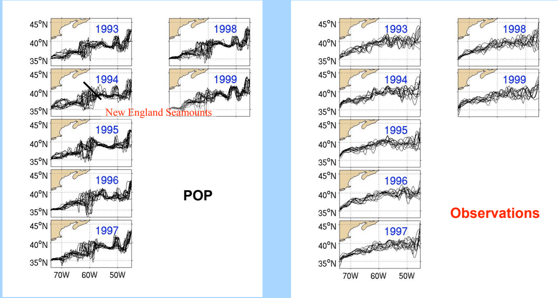


•Gulf Stream Position
- –POP (located to the south of obs)
- –DATA
- –MERCATOR



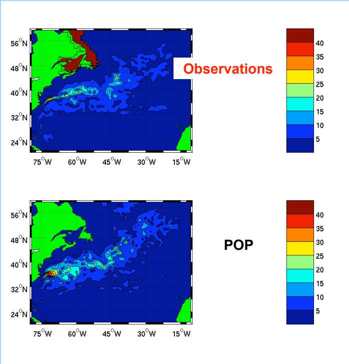
Variability of the Gulf Stream position

•POP (compared to observations)
- –Defined by location of maximum geostrophic flow
- –Variability comparable, but has different zonal structure
- –Node near the New England Seamount
- –Permanent meander downstream of Seamounts
- –Large variability upstream



Interannual sea surface height variance

- 1993-1999 Interannual SSH variance (cm)
  - – Amplitude comparable
  - – Larger variability upstream in POP
  - – Meridional scale of variability larger in POP



Heat Budget

•Calculate contribution to heat content from advection and surface heat flux (all in Watts/m^2)
- –Average over boxes
- –Remove seasonal cycle
- –Low pass for interannual signal
- –Positive indicates heating

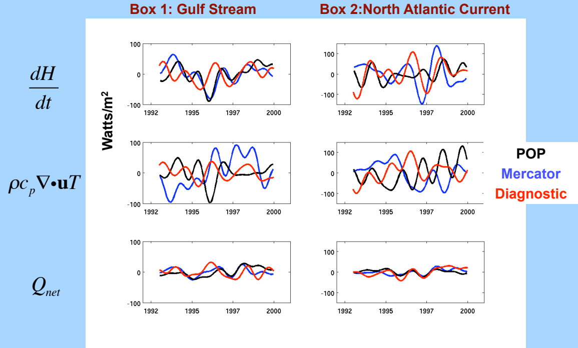
$$\frac{dH}{dt} = \frac{d}{dt}\iiint \rho c_p T dxdydz / Area$$ Heat content tendency

$$\rho c_p \nabla\cdot\mathbf{u}T = \rho c_p \iint \mathbf{u}T\cdot\hat{n}\,d\mathbf{l}dz / Area$$ Heat transport convergence

$$Q_{net} = \iint Q dxdy / Area$$ Surface heat flux

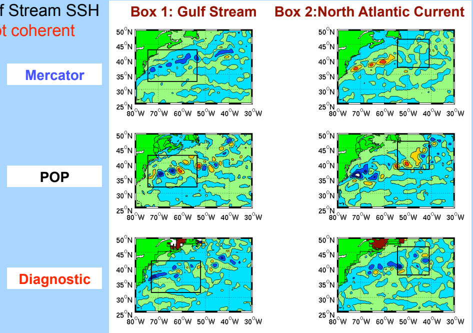
Heat budget terms

•Averaged over the Gulf Stream and North Atlantic Current
- –Heat fluxes agree (by construction)
- –Heat content tendency agrees better in Gulf Stream (Box 1)
- –Little agreement in heat transport convergence
- –In all cases, advection controls heat content



Heat transport convergence regressed onto SSH

•Box 1 Low SSH upstream gives high heat transport convergence
•Box 2 Little agreement: high heat transport convergence from:
Mercator: High Gulf Stream SSH
POP: Low Gulf Stream SSH
Diagnostic: Not coherent



Conclusions

Analysis of Gulf Stream and North Atlantic Current interannual variability in SSH, heat content and heat transport convergence in the three models shows:

•Mean flow well represented in POP, including the Northwest Corner.

•Interannual variability in POP SSH has large maximum near coast, and large meridional extent, with node near New England Seamounts.

• Heat content tendency in POP agrees well with Mercator in Box 1, but not with Diagnostic. Heat transport convergences do not agree in either box.

• For all models, heat transport convergence controls heat content in both boxes, with net heat flux playing a secondary role.

• Despite disagreement in time series, the mechanisms for heat transport convergence are the same in the all three models in the Gulf Stream (Box 1). Low SSH (increase in Gulf Stream transport) results in an increase of heat advected into the box.

•There is no agreement in Box 2, with Mercator and POP giving opposite responses.

•There is large vertical exchange of heat (not shown) and in Box 2, likely interaction with deep circulation which is not modeled in Diagnostic.

References

Dong, S. and K.A. Kelly, 2004: Heat budget in the Gulf Stream region: the importance of heat storage and advection, J. Phys. Ocean., 34, 1214-1231.

Maximenko, N. A., and P. P. Niiler (2004), Hybrid decade-mean global sea level with mesoscale resolution, in Recent Advances in Marine Science and Technology, edited by N. Saxena, pp. 55-59, PACON International.